Research Note

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
OGDEN UTAH

U.S. Forest Service
Research Note INT-36 1965

PREPARING REPRODUCIBLE PINE NEEDLE FUEL BEDS

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ABSTRACT

Describes techniques, developed and tested over a 3-year period, for collecting and conditioning pine needles and for preparing uniform fuel beds from them. These fuel beds had approximately identical burning characteristics and functioned satisfactorily in studies of rates of fire spread and effectiveness of chemical fire retardants.

Free-burning fires have been investigated at the Northern Forest Fire Laboratory for the past 4 years. This paper describes the preparation of uniform fuel beds of ponderosa pine and white pine needles necessary to the conduct of experiments on fire characteristics. To study fire characteristics, it was necessary to develop a fuel bed having reproducible features. Could a technique be developed for constructing a fuel bed that would be reproducible? This paper describes the preparation of such a fuel bed.

For series of controlled experimental fires burned in determining fire characteristics, uniform fuel beds having reproducible features that will assure exactly comparable burning conditions are a prime necessity. The major features of a uniform fuel bed are the loading per unit area and the compactness of the fuel. This paper describes a technique that has been developed, through 4 years' experience at the Fire Laboratory, for preparing such reproducible fuel beds of needles from ponderosa pine and white pine.

FUEL COLLECTION

Collecting a sufficient quantity of recently cast dead needles insures consistency in fuel texture and calorific content. The current season's needle casts, collected in the autumn, are best for use in experimental burning because they have not been subjected to weathering and decay.

Needles should be collected from the ground underneath a pure stand of the desired species. The collection area should be prepared in advance by removing surface litter so as to provide uniform fuel with a minimum of cleaning.

A grass rake has worked best for raking the needles into piles. Needles have been damaged less when they were bulk loaded into the bed of a truck than when they were sacked. They were then transported to a storage area for cleaning and drying. The cleaning was performed by dropping the needles in front of a circulating fan into a wire basket and removing any large pieces of foreign matter by hand. The circulating fan separated most of the finer foreign particles from the needles. The needles were then scattered uniformly about the floor of the storage room and turned twice a day until dry. After drying, they were stored in open bins in the warehouse until needed.

The two conditioning chambers at the Northern Forest Fire Laboratory bring fuels to desired fuel moisture content. These chambers are vapor-sealed and have automatic temperature control and forced-air circulation. Relative humidity in these chambers is held constant by use of saturated salt solutions.

Each chamber accommodates four 24- by 36- by 10-inch wire baskets, each of which holds about 10 pounds of fuel; and nine trays, each of which contains 1 gallon of salt solution (fig. 1). The desired relative humidity is established by circulating air over these trays of saturated salt solution and through the baskets of pine needles. The 9 gallons of salt solution were ample to condition 40 pounds of fuel per cabinet. The fuel moisture level was established by the relative humidity of the air.

Figure 1.--Loading ponderosa pine needles into conditioning cabinet.

Many types of inorganic salt solutions[1] will maintain constant levels of relative humidity in an enclosed chamber. To be most useful in conditioning fuels, the solution should be able to maintain a fairly uniform relative humidity over a wide range of temperatures. Silica gel was used as a desiccant to obtain an experimentally determined relative humidity of 6.5 percent at 90° F. Several inorganic salts proved to be effective in the conditioning of needle fuels (table 1).

Under any given environmental condition, different fuels may have different equilibrium moisture contents. White pine needles had a higher moisture content than ponderosa pine needles under identical conditions in the conditioning cabinets (table 1).

Table 1.--Inorganic salts for fuel conditioning

Salt	Chemical formula	Humidity condition determined--				Approximate moisture content	
		Experimentally		Theoretically		White pine	Ponderosa pine
		Percent	Degrees F.	Percent	Degrees F.	- - - Percent - - -	
Potassium hydroxide	KOH	9	90	8	77	4.6	3.8
Lithium chloride	LiCl	15	90	11	91 ± 14	5.5	4.5
Potassium acetate	$KC_2H_3O_2$	22	90	20	77	6.5	5.7
Magnesium chloride	$MgCl_26H_2O$	30	90	31.5	96 ± 10	8.5	7.3
Magnesium nitrate	$Mg(NO_3)_2.6H_2O$	50	90	51.5	91 ± 14	11.6	9.6
Sodium chloride	NaCl	75	90	75	80 ± 25	15.2	12.8

[1] Wexler, Arnold, and Hasegawa, Saburo. Relative humidity-temperature relationship of some saturated salt solutions in the temperature range 0° to 50° C. Jour. Res. Natl. Bur. of Standards 53(1). Res. Paper 2512 794/19 801/26 pp., Washington: Govt. Printing Office. 1954.

See also: Spencer, H. M. Laboratory methods for maintaining constant humidity. International Critical Tables of Numerical Data Physics, Chemistry, and Technology. Vol. 1, pp. 67-68. New York: McGraw-Hill Book Co. 1926.

The relative humidity of the cabinets was brought to the desired percent before the fuel was put in place. The fuels had been predried in an oven at 125° F. for approximately 2 hours before being placed in the cabinets. A difference in stabilized moisture content of the fuel is found if the equilibrium point is approached from above or below ambient conditions. By oven-drying first, the equilibrium point of the fuel was always approached from the low moisture content side. This procedure was more important at the lower relative humidities.

Xylene distillation[2] was used to determine the equilibrium moisture content of each fuel. Two samples of fuel were taken from each cabinet, and a xylene determination of moisture content was made on each. When readings of fuel moisture content became consistent, the fuel was considered to have reached equilibrium with environmental conditions. The moisture content of most samples did not vary more than ±0.5 percent daily after 1 week's conditioning. Fuel was then at a stable moisture content.

FUEL LOADING

The fuel beds were prepared in a room having environmental conditions identical to those that existed in the conditioning cabinets. This prevented the moisture content from changing during fuel bed preparation.

Each fuel tray consisted of a $\frac{3}{4}$-inch asbestos board 24 inches wide by 8 feet long, with 3-inch-high wire mesh sides, indented 3 inches on each side. The fuel bed was 18 inches wide. The wire mesh sides were lined with paper to eliminate edge effects and thereby simulate an infinite-width fuel bed. The paper had been treated with saturated diammonium phosphate solution to prevent it from flaming and thereby influencing the rate of fire spread. Paper treated with diammonium phosphate will not burn but will char. The bottom of each tray was covered with aluminum foil with its reflective side up, and then with a layer of asbestos paper.

Compactness of the fuel beds[3] affects burning rate. Compactness of fuel loaded into large baskets for conditioning varies from top to bottom. This variation is caused by unavoidable shaking of the baskets during loading and unloading and also by normal settling of the fuel during conditioning. The longer needles are supported near the top whereas the shorter ones sift toward the bottom. This variation in compactness throughout the fuel must be considered in constructing reproducible fuel beds.

We devised a method of stratification to control compactness in each fuel bed. Needles from the conditioning baskets were weighed into small separate baskets, each containing 1 pound. The top layer of needles removed from any conditioning cabinet basket was divided and placed in three individual baskets, each containing 1 pound. The middle layer likewise was removed and divided equally among three baskets. The bottom 3-pound layer was divided the same way. Each fuel bed used in experimental burnings contained 6 pounds of needles, and three beds were usually burned in a day. Therefore, it was necessary to weigh out 18 baskets of conditioned needles from two conditioning cabinet baskets and then divide them into three groups according to whether they came from the top, middle, or bottom layer of the conditioning cabinet basket.

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[2] Buck, C. C., and Hughes, John E. The solvent distillation method for determining the moisture content of forest litter. Jour. Forestry 37(8): 645-651. 1939.

[3] Anderson, Hal E., and Rothermel, Richard C. Influence of moisture and wind upon the characteristics of free-burning fires. Tenth International Symp. on Combustion Proc. 10 pp., illus. Cambridge, England, 1964.

We have developed the following procedure for building reproducible fuel beds having uniform compactness:

1. Random selection of one basket of needles from the six 1-pound baskets from the bottom layer of the two conditioning baskets.

2. Distribution of these needles in a small ridge along the middle of the first 4 feet of the fuel bed. (Workers wear gloves to prevent perspiration from affecting moisture content of the needles.)

3. Needles are worked outward toward sides of the tray until a uniform layer 1 inch deep is formed (fig. 2).

4. Repeat these operations for the other half of the fuel bed.

5. Random selection of two of the 1-pound baskets from the middle layer in the conditioning baskets.

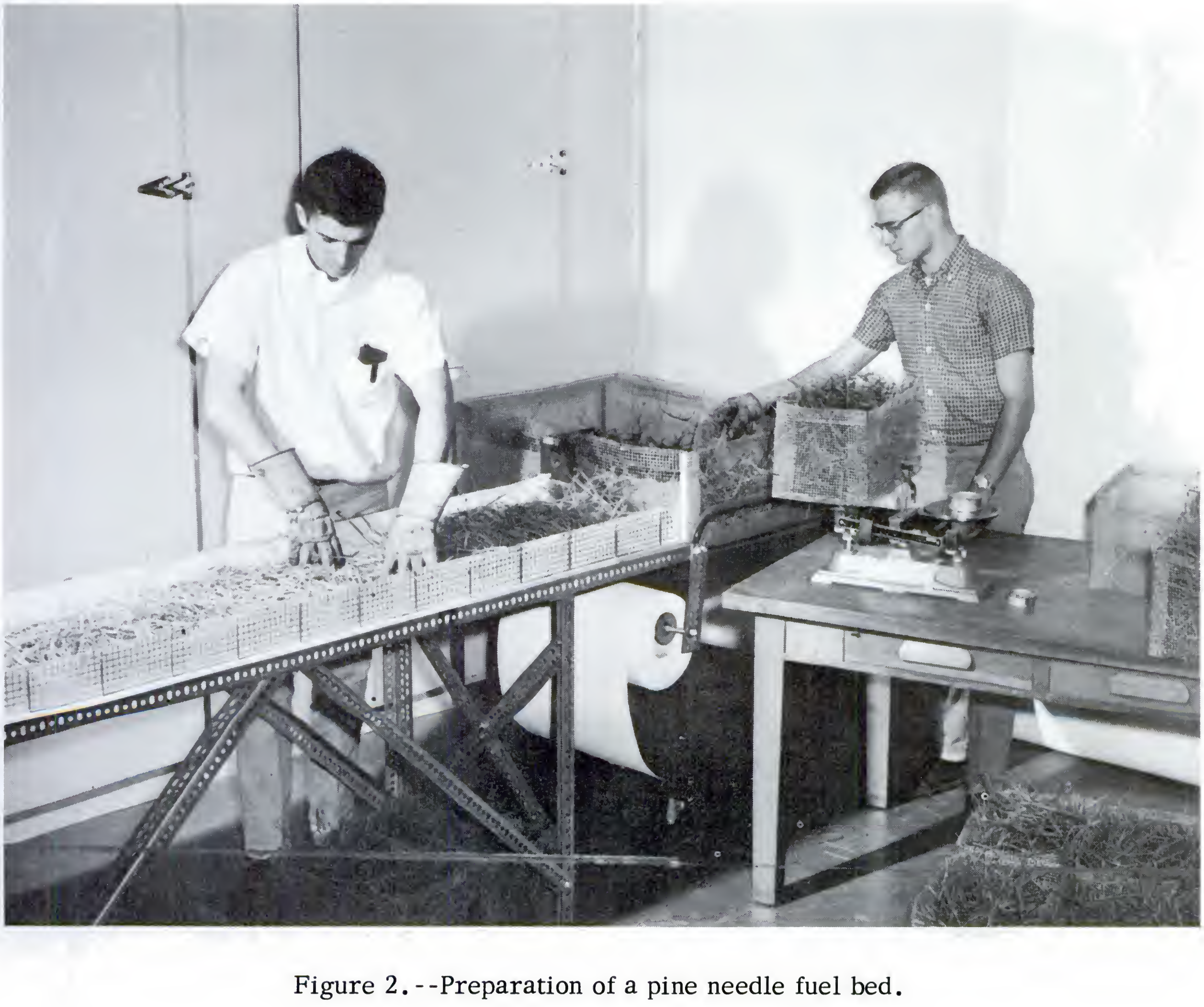

Figure 2.--Preparation of a pine needle fuel bed.

6. Spreading these needles evenly over those already in the fuel bed to a total depth of 2 inches.

7. Similar selection and spreading of 2 pounds of needles from the top layer of the conditioning baskets.

8. Trimming with scissors any needles that protrude above the 3-inch height of the fuel tray.

Fuel beds constructed by this system produced very similar results. The graph (fig. 3) indicates the uniform burning rate of the fuel bed due to uniform fuel loading. The even burning rates also indicate the high degree of fuel bed reproducibility that was achieved.

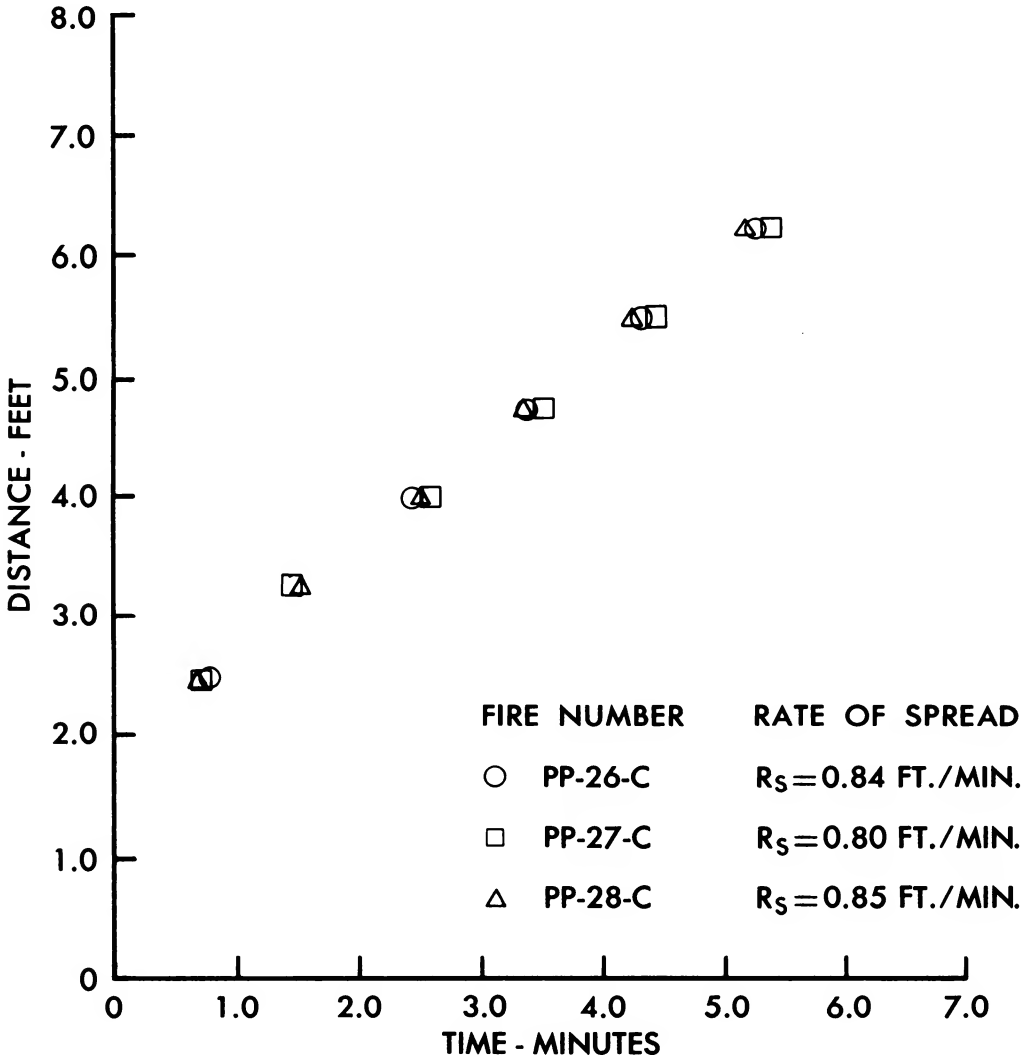

Figure 3.--Rate of spread of three fires in ponderosa pine needles.
Relative humidity = 15 percent.
Dry bulb temperature = 90° F.

During the past 3 years, more than 200 fuel beds prepared by this method have been burned.[4] This same method of fuel bed preparation was used in numerous experimental burns designed to evaluate effectiveness of various chemical fire retardants.[5]

SUMMARY

Beds of pine needles for controlled experimental burnings should be constructed so as to provide reproducible burning conditions. Such fuel beds should be as free as possible from foreign matter (leaves, twigs, bark, and dust) and should have as uniform moisture content and compactness as possible.

To provide such reproducible burning conditions for experiments at the Northern Forest Fire Laboratory, fuel is collected from pure stands of the designated tree species and cleaned mechanically. It is then dried in ovens and conditioned to uniform moisture content in baskets in specially constructed vapor-sealed chambers equipped for circulating air over saturated solutions of specified salts. Needles thus prepared are divided according to whether they were in the top, middle, or bottom layer of conditioning baskets, and weighed into 1-pound units. These in turn are distributed evenly into corresponding 1-inch layers in the trays specially constructed and prepared for controlled burning.

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[4] Anderson, Hal E. Mechanisms of fire spread, research progress report No. 1. U.S. Forest Serv., Intermountain Forest & Range Expt. Sta. Res. Paper INT-8, 20 pp., illus. 1964. (See also Anderson and Rothermel, op. cit.)

[5] Hardy, Charles E., Rothermel, Richard C., and Davis, James B. Evaluation of forest fire retardants--a test of chemicals on laboratory fires. U.S. Forest Serv., Intermountain Forest & Range Expt. Sta. Res. Paper 64, 33 pp., illus. 1962.